Asian Herpetological Research 2012, 3(3): 175–183
DOI: 10.3724/SP.J.1245.2012.00175

Effect of Check Dams on Amphibian Assemblages along Ephemeral Streams in a Tropical Deciduous Forest in Thailand

Ratchata PHOCHAYAVANICH[1, 2], Wichase KHONSUE[2] and Noppadon KITANA[2*]

[1] *Biological Science Program*, *Faculty of Science*, *Chulalongkorn University*, *Pathumwan, Bangkok* 10330, *Thailand*
[2] *Department of Biology*, *Faculty of Science*, *Chulalongkorn University*, *Pathumwan, Bangkok* 10330, *Thailand*

Abstract Numerous check dams have been constructed in many countries, but there continues to be very limited scientific evidence of their effect on biotic community. Since amphibians are highly sensitive to moisture changes, amphibian assemblages were used as a monitoring parameter to evaluate the effects of check dams on biotic components in this study. Comparison of amphibian assemblages between check dam and non-check dam areas was conducted along ephemeral streams in a tropical deciduous forest of the Chulalongkorn University Forest and Research Station in Nan Province, Thailand from April 2009 to March 2010. Five transects, including the stream transect, and 5, 10, 25, and 50 m terrestrial transects, were used for amphibian surveys between the two areas. Physical factors related to moisture were also compared between these areas. It was found that hydroperiod in the check dam stream was significantly higher than that in the non-check dam stream. Soil moisture content at most terrestrial transects in the check dam area was significantly higher than that in the non-check dam area, while similarity in leaf litter moisture content was found in most transects. Simpson's index of diversity indicated that amphibian diversities in all transects were equally diverse between the two areas in both wet and dry seasons. Cluster analysis of similarity in species composition indicated that amphibian composition in the check dam stream was distinct from that in the non-check dam stream in the wet season or the functional period of the check dam. However, the amphibian compositions in both check dam and non-check dam streams were similar to each other in the dry season. No significant check dam effect was found on species composition in the terrestrial habitats in both seasons. Overall, using a highly moisture-sensitive vertebrate as a bio-indicator, the results showed that the check dams and the changes in moisture-related physical factors appear to have little short-term effect on amphibian assemblages.

Keywords moisture, temporary stream, species diversity, species composition

1. Introduction

Drought has been reported in many parts of the world. The Intergovernmental Panel on Climate Change (IPCC) reported that some regions become susceptible to prolonged periods of drought due to climate change (IPCC, 2007). Several management methods with varying effects on the environment have been employed to mitigate this problem including check dam construction. The check dams are small dams constructed across a gully or stream to 1) reduce the velocity of water flow, 2) monitor and entrap sedimentation, 3) increase infiltration of water into the surrounding soil, in order to 4) increase the vegetation, and 5) reduce the peak flood discharge (Gray and Leiser, 1982; Solaimani *et al*., 2008). Check dams can be made from very diverse materials, such as low-price local materials (bamboo, wood, log, clay, rock) and high-cost concrete, resulting in varying life spans (Department of Local Administration, 2008). In Thailand, check dams have been initially and successfully implemented in rural areas according to the advice of His Majesty the King of Thailand since they can be simply constructed by local people with minimal investment, and effectively operated to prolong the water period. As a

* Corresponding author: Dr. Noppadon KITANA, from Chulalongkorn University, Pathumwan, Bangkok, Thailand, with his research focusing on the reproductive biology and environmental biology of amphibians and reptiles.
E-mail: noppadon.k@chula.ac.th
Received: 27 February 2012 Accepted: 10 August 2012

result, many governmental offices and the private sector businesses have participated in the construction of check dams throughout the country.

Although numerous check dams have been built, there are still few reports on the potential effect of check dams on the environment. Shieh *et al*. (2007) concluded that check dams not only changed the physical characteristics of the river, but also had negative impacts on the biodiversity of the river by 1) altering the migration of organisms to breeding sites, 2) partitioning the population and community of animals in the river, and 3) reducing the habitat diversity. However, information from river habitats was not universally applicable since most habitat types selected for check dam construction in Southeast Asia were primary order or secondary order streams, which are usually non-permanent streams or ephemeral streams (Department of Local Administration, 2008). Previous reports showed that check dams can increase absorption rates of underground water and the stream hydroperiod (Watershed Conservation and Management Office, 2008). Treepatanasuwan and Ploychareon (2006) reported that the numbers of seedlings and saplings in a dry evergreen forest in the check dam construction area were higher than in an area with no check dam. Therefore, the effect of check dams on biotic communities, especially animal communities, in this habitat type is still needed to be studied. Recently, the Chulalongkorn University has started a plan to construct 100 check dams in the University Forest and Research Station in Nan Province, northern Thailand. The plan allowed us to set up a comparative study on the effect of check dams on the biotic community in the vicinity of the check dams.

The main objective of the construction of check dams is to prolong the hydroperiod and increase moisture in the area. Therefore, the organisms used as indicators to detect the effect of check dams on the biotic component in the ecosystem should be sensitive to moisture change. In this study, amphibians were selected as monitoring species based on their following water dependence characters. First, compared to other terrestrial vertebrates, the rate of evaporative water loss is very high in amphibians, and second, amphibians typically require more water than other terrestrial vertebrates for excretion of ions and nitrogen wastes due to the limited concentrating capacity of their kidneys (Shoemaker *et al*., 1992). Moreover, most of amphibian lava and eggs need to develop in the water (Duellman and Trueb, 1994). Changes in physical factors could directly/indirectly affect the amphibian assemblages in nature. Snodgrass *et al*. (2000) found the positive relationship between the hydroperiod and amphibian species richness. Pechmann *et al*. (1989) reported that amphibian diversity was affected by either increasing or decreasing of the hydroperiod. Werner *et al.* (2007) also reported the effect of the hydroperiod on the presence or absence of tadpoles. Wells (2007) suggested that leaf litter moisture can limit the distribution of some species of ground dwelling frogs, and Allmon (1991) also found that frog diversity and litter moisture are positively correlated.

Since these physical factors were expected to change in response to the construction of check dams, the amphibian assemblage, a sensitive indicator of the health of the biotic community, are thus expected to change too. Therefore, the objective of this study is to explore the effects of check dams and the resulting changes in physical factors on the amphibian assemblage.

2. Material and methods

2.1 Study area The study site, the Chulalongkorn University Forest and Research Station (CFRS), is a 300-ha area located in Lai Nan Sub-district, Wiang Sa District, Nan Province, Thailand (UTM zone 47Q: N 2051960–2054260 and E 0688400–0690360; Figure 1). The annual mean rainfall during 2000–2009 was 1159.6 mm. The mean air temperature and relative humidity in that period was 26.5°C and 76.2%, respectively. This area is covered by a deciduous forest composed mainly of dipterocarp and other deciduous plants (Dumrongrojwatthana, 2004). During the wet season, the streams are filled with flowing water only by heavy rains, and then they become stagnant water and dry out within 1 to 2 weeks because of no rain. The streams are completely dry in the dry season, even the streams with check dams. Therefore, the check dams have no obvious effect on the environment during this period.

2.2 Construction scheme of check dams When this study was started in 2009, 27 check dams had been constructed at the CFRS (Figure 1). Two non-connected streams within the CFRS that exhibited similar physical characteristics and approximately 500 m apart were selected as study sites. One of the two streams with 13 check dams constructed is designated as Stream A, and the other with no check dams as Stream B. Since both streams are closely located at the CFRS with the same type of forest, the amphibian assemblages are presumed to be highly similar under unmodified conditions. Along Stream A, the check dams were completed in 2008. However, the construction of check dams is planned and the construction sites are marked along Stream B, which were used as starting and end points of stream transects in

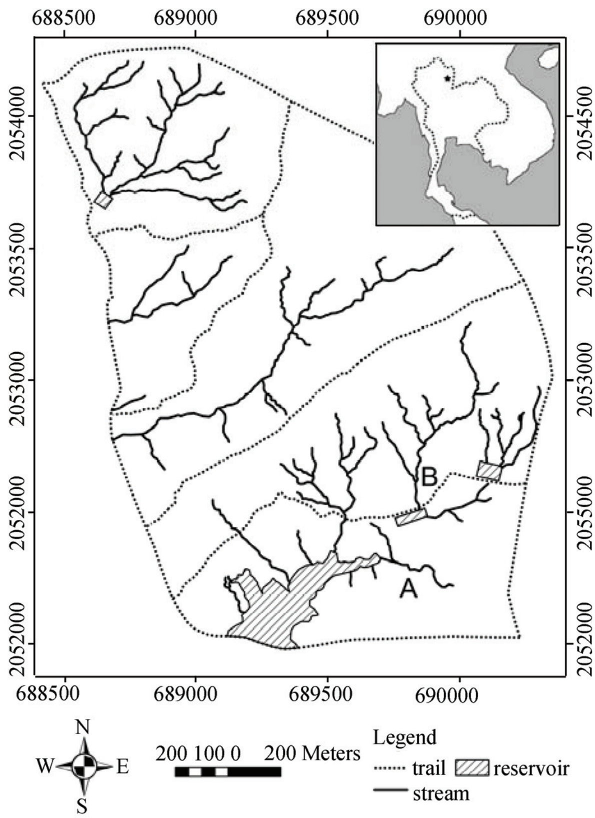

Figure 1 Map of the Chulalongkorn University Forest and Research Station in Nan Province, Thailand (modified from Dumrongrojwatthana, 2004). A: Stream with check dam construction completed in 2008; B: Stream without check dam. Inset shows a map of Thailand with a star (★) marking the location of the study area in Nan Province.

this stream.

The height of check dams was designed almost the same high as the stream banks in order to trap water at a maximum level and avoid flooding onto both sides of the stream. The distance between check dams was determined by the maximum water level of the downstream check dam (Figure 2). Check dams were constructed continuously up to the head water of the stream. The mean and range values of check dam height, distance between check dams, stream width, and area of surface water of check dam and non-check dam streams are shown in Table 1.

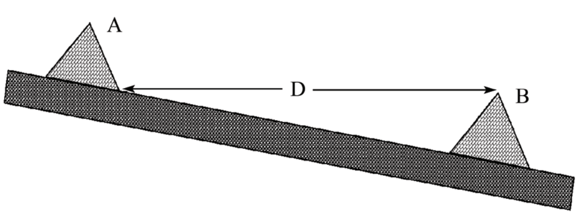

Figure 2 Diagram of check dam showing the distance between two check dams. A: Upstream check dam; B: Downstream check dam; D: Distance between check dams.

2.3 Amphibian survey Two types of transects, including 1) stream transect for aquatic habitat and 2) strip-transect for terrestrial habitat, were used for amphibian survey in the check dam and non-check dam areas.

Ten stream transects were designated in each stream, and each stream transect was started from one check dam along check dam stream or the planned check dam construction site along non-check dam stream to the next check dam or the next check dam construction site. The width of stream transects was similar to the stream width or approximately 2 m. Four permanent strip-transects of 2 m wide were located parallel to each stream transect with the perpendicular distance of 5, 10, 25, and 50 m from the stream, respectively. So, there were 40 strip-transects in each area.

Active survey based on transect sampling (Heyer *et al*., 1994) was used to detect amphibians along both streams and strip transects. Amphibians in water, on bare ground, under leaf litter and on plants with height less than 1.5 m were recorded from these transects. Each survey began at the starting point of the transect and extended to the end of transect. Amphibians were identified to species and numbers of individuals in each species were recorded. Since the transects are varied in length, the number of amphibians in each species was divided by total area (m^2) of the transect and recorded for data analysis. In each area, a total of three transects were surveyed during day time (09:00–12:00 h) and another three transects during night time (19:00–22:00 h) of each day. The selection of these transects was on a random basis. During each survey, special care was given to avoid habitat disturbance in the remaining transects. In each month, the surveys were conducted for 16 consecutive days until every transect was surveyed. The data obtained from April 2009

Table 1 The characteristics of check dam and non-check dam streams.

Characteristics	Check dam stream	Non-check dam stream
Check dam height (m)		
Mean ± SD	0.81 ± 0.20	-
(Range of value)	(0.40–1.00)	-
Distance between check dams / Length of stream transect (m)		
Mean ± SD	33.24 ± 0.11	25.30 ± 8.99
(Range of value)	(11.35–75.85)	(15.85–47.85)
Stream width (m)		
Mean ± SD	2.53 ± 0.56	1.81 ± 0.56
(Range of value)	(1.85–3.45)	(1.15–3.05)
Area of surface water (cm^2)		
Mean ± SD	81.21 ± 43.63	47.54 ± 25.56
(Range of value)	(21.00–140.32)	(18.23–98.09)
Age (yrs)	2.14 ± 0.93	1.27 ± 0.82

to March 2010 were analyzed and are presented in this article.

2.4 Physical factors Monthly total rainfall and mean air temperature were collected from the nearest meteorological station. Numbers of days that water body existed in each stream were recorded. Leaf litter and soil were collected from each terrestrial transect surveyed. Their wet and dry weights were measured to determine the percentage of water content.

2.5 Data analysis Data were analyzed separately according to 1) climatic conditions (wet and dry seasons) and 2) transect groups (one stream transect, and four terrestrial transects located at 5, 10, 25, and 50 m from the stream). Since both the study streams are ephemeral, no water exists during the dry season. Therefore, the effect of the check dams on ecosystem is minor in the dry season.

For physical factor analysis, monthly rainfall and mean air temperature were plotted against months in a climate diagram in order to indicate the wet and dry seasons (Walter *et al*., 1975). In the climate diagram, a month with total rainfall (mm) greater than twice of the mean air temperature (°C) was designated as the wet season. In each season, the numbers of days with water in the streams were compared between check dam and non-check dam streams by *t*-test. In each transect, leaf litter and soil moisture contents were compared between check dam and non-check dam areas by either *t*-test or Mann-Whitney *U*-test.

For amphibian assemblage analysis, the assemblage data (species diversity and species composition) from both check dam and non-check dam areas were grouped into five transect groups, that is, the stream transect, and 5 m, 10 m, 25 m, and 50 m transects. All assemblage parameters in this study were calculated based on average density of each amphibian species in each transect group. The species diversity in each transect group was determined by Simpson's index of diversity (1-*D*). Diversity values were compared between check dam and non-check dam areas for each season and transect group. For species composition or relative abundance of different amphibian species, the similarity in species composition among transect groups in each season were determined by a cluster analysis with Sorensen (Bray & Curtis) distance measurements using PC-ORD software version 4.25 (McCune and Mefford, 1999). Afterward, the significant differences in species composition among these transect groups were determined by non-parametric analysis of similarity (ANOSIM). If a significant difference among the groups was obtained, pair-wise comparisons were conducted to determine the significant difference in species compositions between each pair of transects. ANOSIM analyses were performed by the vegan-package in RStudio software using 1,000 permutations to generate *R* {mean ranks between groups – mean ranks within groups / [N (N-1) / 4] } and *P* values (R Development Core Team, 2011).

3. Results

3.1 Physical factors The climate diagram indicated that the wet season in this area extended from April to September in 2009, while the dry season from October 2009 to March 2010 (Figure 3). Based on this information, it was found that the hydroperiod in the stream transect was significantly longer in the check dam stream than those in the non-check dam stream in both wet and dry seasons (Table 2). In terrestrial transects, there were significant seasonal differences in soil and leaf litter moisture contents. In the wet season, the soil moisture contents at 10 and 25 m transect groups were significantly higher in the check dam than in the non-check dam areas, whereas the values at 5 and 50 m transect groups were not significantly different between these two areas (Table 3). In the dry season, the soil moisture content in the check dam area was significantly

Table 2 Average number of days when water bodies are present in check dam and non-check dam streams.

Seasons	Check dam (Mean ± SD)	Non-check dam (Mean ± SD)
Wet season	50.55 ± 19.73	28.31 ± 20.95 *
Dry season	12.31 ± 3.40	5.27 ± 4.55 *

* indicates a significant difference from check dam stream at $P \leq 0.05$.

Table 3 Soil moisture content at 4 terrestrial transects in check dam and non-check dam areas.

	Type of statistics/ value	Check dam area	Non-check dam area
Wet season			
5 m from stream	*U*-test / mean rank	64.18	56.83
10 m from stream	*t*-test / mean ± SD	17.90 ± 8.58	13.48 ± 5.61*
25 m from stream	*t*-test / mean ± SD	14.90 ± 6.62	12.21 ± 6.26*
50 m from stream	*t*-test / mean ± SD	12.90 ± 7.21	12.50 ± 4.68
Dry season			
5 m from stream	*U*-test / mean rank	73.47	47.53 *
10 m from stream	*U*-test / mean rank	73.44	47.56 *
25 m from stream	*U*-test / mean rank	68.02	52.98 *
50 m from stream	*U*-test / mean rank	67.97	53.03 *

* indicates a significant difference from check dam area at $P \leq 0.05$. Rank = rank order in ordinal scale of the measured moisture content, not an absolute quantity of moisture content.

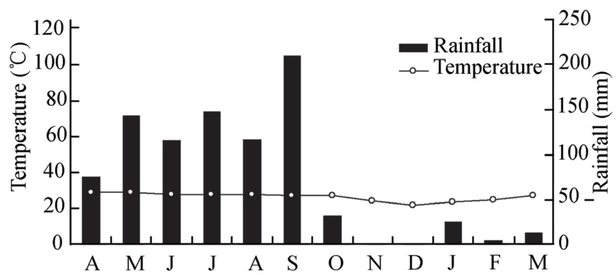

Figure 3 Climate diagram used to determine wet and dry seasons in the study area between April 2009 and March 2010.

higher than in the non-check dam area at all the transects. There was almost no significant difference in leaf litter moisture content between the check dam and non-check dam areas in both seasons (Table 4), with the exception of the 25 m transect in the wet season where significantly higher leaf litter moisture was found in the check dam area.

3.2 Amphibian assemblage We found 16 amphibian species in the study area. Among them, 15 species were found in both check dam and non-check dam areas. The families containing those species were similar in the two areas (Table 5).

During the wet season, amphibian diversities in the check dam and non-check dam areas were similar at all the 5 transects. In the dry season, amphibian diversity in the two areas were also similar, with only an exception at the terrestrial transect 25 m from the stream, at which the amphibian diversity in the check dam area was higher than in the non-check dam area. Overall, the amphibian diversity in most, if not all, transects were similar between the two areas in both wet and dry seasons.

In spite of the comparable diversity, amphibians in the two areas showed site- and season-related difference in pattern of species composition. In the dry season, cluster analysis based on the similarity in amphibian composition among transects showed that the amphibian assemblage pattern could be divided into two groups: 1) check dam and non-check dam streams and 2) all terrestrial transects from the two streams (Figure 4). The results from ANOSIM indicated the significant difference in amphibian compositions among the transect groups. The pair-wise comparisons corroborated the cluster analysis that the amphibian compositions were not significantly different between the check dam (Stream A: Ast) and non-check dam (Stream B: Bst) streams, and the amphibian composition in Ast was significantly different from that in all terrestrial transects. However, it is interesting to note that the amphibian compositions between Bst and most

Table 4 Leaf litter moisture content at 4 terrestrial transects in check dam and non-check dam areas.

	Type of statistics/ value	Check dam area	Non-check dam area
Wet season			
5 m from stream	*U*-test / mean rank	55.19	65.81
10 m from stream	*U*-test / mean rank	66.07	54.93
25 m from stream	*U*-test / mean rank	77.44	49.56 *
50 m from stream	*U*-test / mean rank	61.13	59.88
Dry season			
5 m from stream	*U*-test / mean rank	66.66	54.34
10 m from stream	*U*-test / mean rank	66.43	54.57
25 m from stream	*U*-test / mean rank	66.14	54.86
50 m from stream	*U*-test / mean rank	66.24	54.76

* indicates a significant difference from check dam area at $P \leq 0.05$.

Table 5 Relative abundance of amphibian species in each family in check dam and non-check dam areas.

No.	Family/species	Check dam	Non-check dam
	Bufonidae		
1	*Bufo macrotis*	0.125	0.042
	Ranidae		
2	*Fejervarya limnocharis*	0.037	0.037
3	*Hoplobatrachus rugulosus*	0.001	-
4	*Limnonectes pileatus*	0.001	0.008
5	*Occidozyga lima*	0.016	0.003
6	*Occidozyga martensii*	0.269	0.175
	Rhacophoridae		
7	*Chirixalus doriae*	-	0.003
8	*Polypedates leucomystax*	0.028	0.014
	Microhylidae		
9	*Calluella guttulata*	0.001	0.011
10	*Kaloula pulchra*	0.009	0.017
11	*Microhyla berdmorei*	0.004	0.014
12	*Microhyla butleri*	0.052	0.177
13	*Microhyla fissipes*	0.220	0.223
14	*Microhyla heymonsi*	0.078	0.099
15	*Microhyla pulchra*	0.065	0.045
16	*Micryletta inornata*	0.095	0.132
Total species richness		15	15

Table 6 Simpson's index of diversity at each transect in check dam and non-check dam areas.

	Check dam area	Non-check dam area
Wet season		
Stream	0.80	0.81
5 m from stream	0.73	0.83
10 m from stream	0.67	0.83
25 m from stream	0.74	0.77
50 m from stream	0.76	0.76
Dry season		
Stream	0.78	0.81
5 m from stream	0.80	0.79
10 m from stream	0.69	0.60
25 m from stream	0.74	0.26
50 m from stream	0.71	0.68

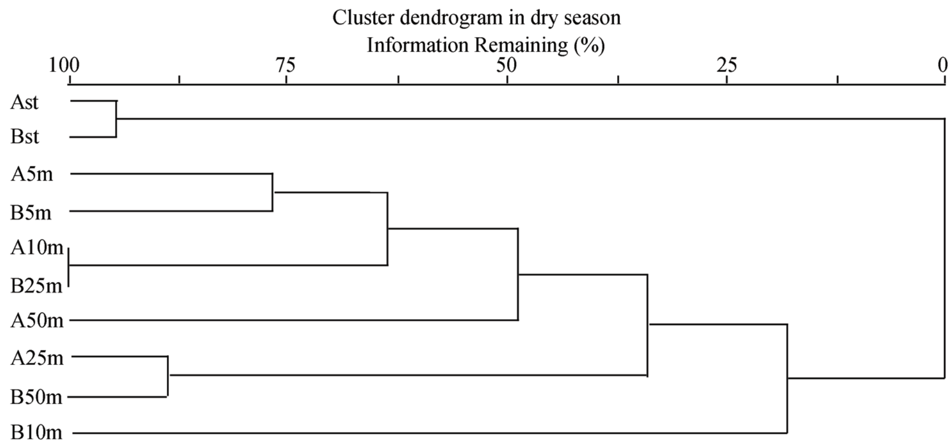

Figure 4 Cluster diagram with Sorensen (Bray & Curtis) distance measurement based on amphibian species composition in every transect of both check dam and non-check dam areas during the dry season.
Ast and Bst: Stream transect group in check dam and non-check dam areas, respectively. A5m and B5m, A10m and B10m, A25m and B25m, A50m and B50m = terrestrial transecsts at 5 m, 10 m, 25 m, and 50 m from the stream in check dam and non-check dam areas, respectively. The same below.

of the terrestrial transects were not significantly different (Table 7).

In the wet season, the results of the cluster analysis showed two patterns of amphibian assemblages (Figure 5), with distinct difference from the dry season. The first group of the cluster was composed of only check dam stream transect, while the second group composed of all other transects. The result from ANOSIM indicated a significant difference in amphibian compositions among these transects. Further, the pair-wise comparisons also confirmed that assemblage of amphibians at Ast was significantly different from that at Bst during the check dam functional period (Table 8). In addition, the compositions of amphibians in both the streams were significantly different from those of the terrestrial transects in the wet season.

Table 7 Pair-wise comparisons of amphibian compositions between stream transects vs. terrestrial transects and check dam stream transect *vs*. non-check dam stream transect in the dry season.

Transect			R	P value
Check dam stream	*vs.*	A5m	0.5299	*0.003
		A10m	0.5273	*0.002
		A25m	0.6033	*0.001
		A50m	0.7708	*0.003
		B5m	0.4384	*0.001
		B10m	0.7622	*0.005
		B25m	0.5931	*0.006
		B50m	0.7044	*0.004
Non-check dam stream	*vs.*	A5m	0.1048	0.224
		A10m	0.05263	0.309
		A25m	0.1696	0.086
		A50m	0.5511	*0.005
		B5m	0.04353	0.278
		B10m	0.008621	0.466
		B25m	0.04301	0.557
		B50m	0.1526	0.131
Check dam stream (Ast)	*vs.*	Non-check dam stream (Bst)	0.082	0.16

* indicates a significance of R statistics at $P \leq 0.05$.

4. Discussion

4.1 Effect of check dam on amphibian diversity It is clear that check dams can extend the existence of water in an area. The days of inundation at Ast exceeded those of Bst. On average, the check dam area remained inundated for approximately 22 more days during the wet season and seven days more during the dry season than the non-check dam area. However, amphibian diversity index at each transect was relatively close between the two areas during both wet and dry seasons. In contrast, amphibian diversity or species richness were positively correlated with the hydroperiod in wetland habitat where long-term alteration of hydroperiod was conducted (Pechmann *et al*., 1989; Snodgrass *et al*., 2000). This difference may be due to a relatively short time span since the alteration (the 2nd year of check dam utilization), making it too early to find any change in amphibian diversity. In addition, since this study was conducted in an ephemeral stream, all amphibian species found in this study are the ephemeral pond breeders. With the relatively short period of time that the check dam can prolong the water body (7–22 d), it is unlikely for other frogs such as stream breeders to lay eggs in this stream, and it is not likely for the frogs from other forest types to migrate into this isolated forest patches.

4.2 Effect of check dam on amphibian composition From the cluster results, there is a difference in pattern

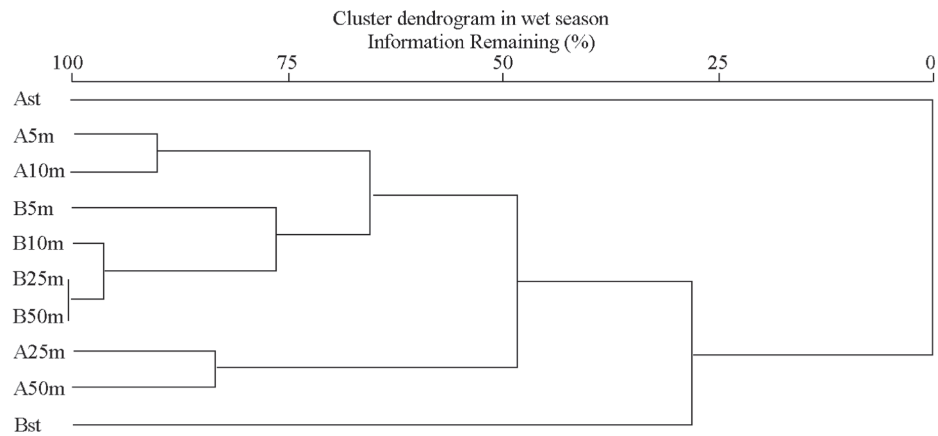

Figure 5 Cluster diagram with Sorensen (Bray & Curtis) distance measurement based on amphibian species composition in every transect of both check dam and non-check dam areas during the wet season.

of amphibian composition between wet and dry seasons. In the dry season, the amphibian compositions in both the streams were similar. However, in the wet season the amphibian composition in Ast was different from those in Bst, indicating that during the check dam functional period the amphibian composition in the stream habitat was greatly affected by the check dams. The species composition might be related to the difference in microhabitat requirements by the amphibians found in this area. In Thailand, Khonsue (1996) reported that, albeit their size similarity, *Microhyla* spp. were normally found in leaf litter, on bare ground or on rocks, but rarely found in water bodies, while *Occidozyga martensii* was commonly found in many habitats including in water bodies. Likewise, the previous reports by Inger (1966)

Table 8 Pair-wise comparisons of amphibian compositions between stream transects vs. terrestrial transects and check dam stream transect vs. non-check dam stream transect in the wet season.

Transect			R	P value
Check dam stream	*vs.*	A5m	0.4927	*0.001
		A10m	0.4554	*0.001
		A25m	0.6571	*0.001
		A50m	0.9041	*0.001
		B5m	0.4258	*0.001
		B10m	0.5762	*0.001
		B25m	0.7429	*0.001
		B50m	0.5698	*0.001
Non-check dam stream	*vs.*	A5m	0.25	*0.005
		A10m	0.3636	*0.001
		A25m	0.3817	*0.002
		A50m	0.6406	*0.001
		B5m	0.1226	*0.037
		B10m	0.1309	*0.035
		B25m	0.1733	*0.04
		B50m	0.1298	*0.034
Check dam stream (Ast)	*vs.*	Non-check dam stream (Bst)	0.3083	*0.003

and Inger and Stuebing (2005) indicated that the frogs in the genus *Occidozyga* were usually found in or near the water body. Since the ephemeral streams used in this study usually dry out a few days in a year with no rain, the presence of check dams in the stream could prolong hydroperiod and provide habitat preferred by some amphibian species such as *Occidozyga martensii*. Therefore, longer hydroperiod in Ast could affect relative abundances of amphibian differently from the un-altered Bst. This effect of check dams on amphibian composition along the stream was minimal in the dry season because there was no rain or water in the check dam stream. As a result, the difference in microhabitats between Ast and Bst caused by the check dam was not evidenced in this period.

The amphibian compositions in the terrestrial habitats between the check dam and non-check dam areas were similar in the wet and dry seasons. This indicates that the presence of check dams has no short-term effect on the amphibian composition in the terrestrial habitats. In the physical factor study, although the soil moisture content in some transects was different between check dam and non-check dam areas, the leaf litter moisture content in all terrestrial transects were similar between the two areas in both wet and dry seasons. Therefore, the similarity of amphibian composition in terrestrial habitats may be related to the similarity in leaf litter moisture in the terrestrial habitats. Wells (2007) suggested that leaf litter moisture can limit the distribution of some ground dwelling frogs in general. Moreover, previous reports indicate that frog diversity and abundance in the tropical Amazon are associated with the leaf litter moisture content (Allmon, 1991). Furthermore, during this relatively short study, there was no change in terrestrial

habitat caused by the check dams. Therefore, similarity in amphibian composition between check dam and non-check dam areas was expected. However, the period of this research is too short to conclude the long-term effect of check dams on amphibian assemblages in this area. In a longer period, the amphibian assemblage could accumulate a check dam effect and could show a subtle change continuously. Therefore, a long-term monitoring study is needed to determine effect of check dams.

5. Conclusion

This study on the effect of check dams on the physical and biological components of a tropical deciduous forest revealed the changes in physical parameters, including longer hydroperiod of the stream habitat and increased soil moisture of the terrestrial habitats. Although the amphibian diversity and composition were found to be affected by these factors (Allmon, 1991; Pechmann *et al*., 1989; Snodgrass *et al*., 2000), the results from this study indicated that the check dams and the changes in the physical factors did not affect the amphibian diversity, and only affected the amphibian composition in the stream during the check dams functional period. Using one of the most moisture-sensitive vertebrates as a bioindicator, the results showed that check dams only had a little effect on amphibian assemblages. Therefore, based on this year-round data, check dams could be regarded as an appropriate way to prolong the hydroperiod in the ephemeral stream with minimal effect on the biological community in the area. However, to determine long-term effect of check dams on amphibian assemblages in the area, a long-term monitoring program is needed. Moreover, as for the effect of check dams on amphibian assemblages in a broader sense, studies need to be conducted in more different streams with varying degrees of hydroperiods, including permanent streams.

Acknowledgement This research was supported by the 2009 Thai Government budget under the Research Program on Conservation and Utilization of Biodiversity, the Center of Excellence in Biodiversity, Faculty of Science, Chulalongkorn University, the Science for Locale Project under the Chulalongkorn University Academic Development Plan, and a Chulalongkorn University Graduate School Thesis Grant. We would like to thank all the staff of the Chulalongkorn University Forest and Research Station for their help in the construction of check dams and for their other supports. We are grateful to Dr. Horold K. VORIS from the Field Museum of Natural History, Chicago, USA and Dr. George R. ZUG from the National Museum of Natural History, Washington D.C., USA for their constructive suggestions and revisions of the English language of this manuscript.

References

Allmon W. D. 1991. A plot study of forest floor litter frogs, Central Amazon, Brazil J Trop Ecol, 7: 503–522

Department of Local Administration. 2008. Check dam construction. Retrieved from http://www.thailocaladmin.go.th/work/e_book/eb1/stan12/p10.pdf 30/12/2008 (In Thai)

Duellman W. E., Trueb L. 1994. Biology of Amphibians. London: The Johns Hopkins Press, 670 pp

Dumrongrojwatthana P. 2004. Impacts of forest disturbance on soil organic matter, soil nutrients and carbon sequestration in Nam Wa Sub-watershed, Nan Province. M.Sc. Thesis. Chulalongkorn University, 191 pp

Gray D. H., Leiser A. T. 1982. Biotechnical slope protection and erosion control (1st Ed). New York: Van Nostrand Reinhold. Cited in Solaimani K., Omidvar E., Kelarestaghi A. 2008. Investigation of check dam's effects on channel morphology (Case study: Chehel Cheshme Watershed). Pak J Biol Sci, 11: 2083–2091

Heyer W. R., Donnelly M. A., McDiarmid R. W., Hayek L. C., Foster M. S. 1994. Measuring and monitoring biological diversity: Standard methods for amphibians. Washington D. C.: Smithsonian Institution Press, 364 pp

Inger R. F. 1966. The systematics and zoogeography of the amphibian of Borneo. Chicago: Field Museum of Natural History, 402 pp

Inger R. F., Stuebing R. B. 2005. A field guide to the frogs of Borneo (2nd Ed). Kota Kinabalu: Natural History Publications (Borneo), 201 pp

Intergovernmental Panel on Climate Change (IPCC). 2007. Climate change 2007: Synthesis report, contribution of working group I, II and III to the fourth assessment report of the Intergovernmental Panel on Climate Change. Geneva: IPCC, 104 pp

Khonsue W. 1996. Species diversity and resource partitioning among amphibians at a stream in dry evergreen forest, Chachoengsao Wildlife Research Center. M.Sc. Thesis. Chulalongkorn University, 111 pp (In Thai)

McCune B., Mefford M. J. 1999. Multivariate analysis of ecological data, Version 4.25. Gleneden Beach, Oregon: MjM Software

Pechmann J. H. K., Scott D. E., Gibbons J. W., Semlitsch R. D. 1989. Influence of wetland hydroperiod on diversity and abundance of metamorphosing juvenile amphibians. Wetlands Ecol Manage, 1: 3–11

R Development Core Team. 2011. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. URL http://www.R-project.org

Shieh C., Guh Y., Wang S. 2007. The application of range of variability approach to the assessment of a check dam on riverine habitat alteration. Environ Geol, 52: 427–435

Shoemaker V. H., Hillman S. S., Hillyard S. D., Jackson D. C., McClanahan L. L., Withers P. C., Wygoda M. L. 1992. Exchange of water, ions, and respiratory gases in terrestrial amphibians. In Feder M. E., Burggren W. W. (Eds.), Environmental physiology of amphibians. Chicago: The University of Chicago Press, 646 pp

Snodgrass J. W., Komoroski M. J., Bryan Jr A. L., Burger J. 2000. Relationships among isolated wetland size, hydroperiod, and amphibian species richness: Implications for wetland regulations. Conserv Biol, 14: 414–419

Treepatanasuwan P., Ploychareon P. 2006. Plant community change in the check dam forestry area at Phu-Phan Royal Development Study Centre, Sakon Nakorn Province. Report of the Forest and Plant Conservation Research Division, Department of National Parks, Wildlife and Plant Conservation, Bangkok, Thailand

Walter H., Harnickell E., Mueller-Dombois D. 1975. Climate-diagram maps of the individual continents and the ecological climatic regions of the Earth. Berlin: Springer-Verlag, 36 pp

Watershed Conservation and Management Office. 2008. Benefit of the check dam. Retrieved from http://www.dnp.go.th/Watershed/checkdam_site/cd_benefit3.htm 22/12/2008

Wells K. D. 2007. The ecology and behavior of amphibians. Chicago: University of Chicago Press, 597 pp

Werner E. E., Skelly D. K., Relyea R. A., Yurewicz K. L. 2007. Amphibian species richness across environmental gradients. Oikos, 116: 1697–1712